It Ain't (Just) Rocket Science

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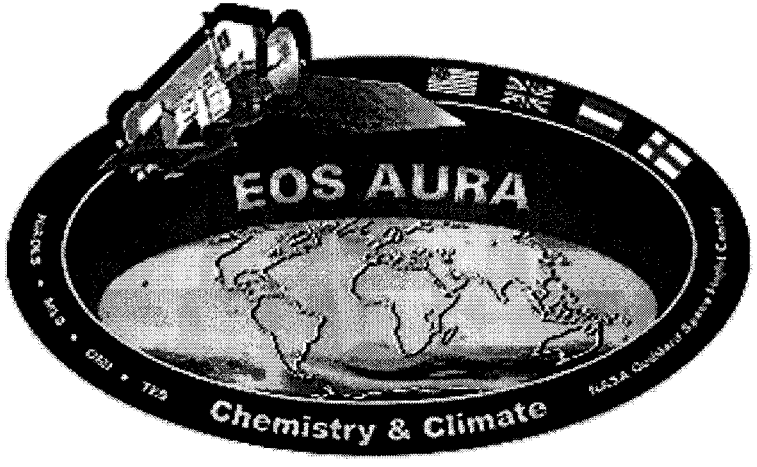
Introduction

- EOS-Aura Mission
- TES Project
- Modeling
  - How scientists model the world
  - Using the UML to support scientific research
  - Role of UML in business process modeling
  - Lessons learned

The EOS Aura Mission



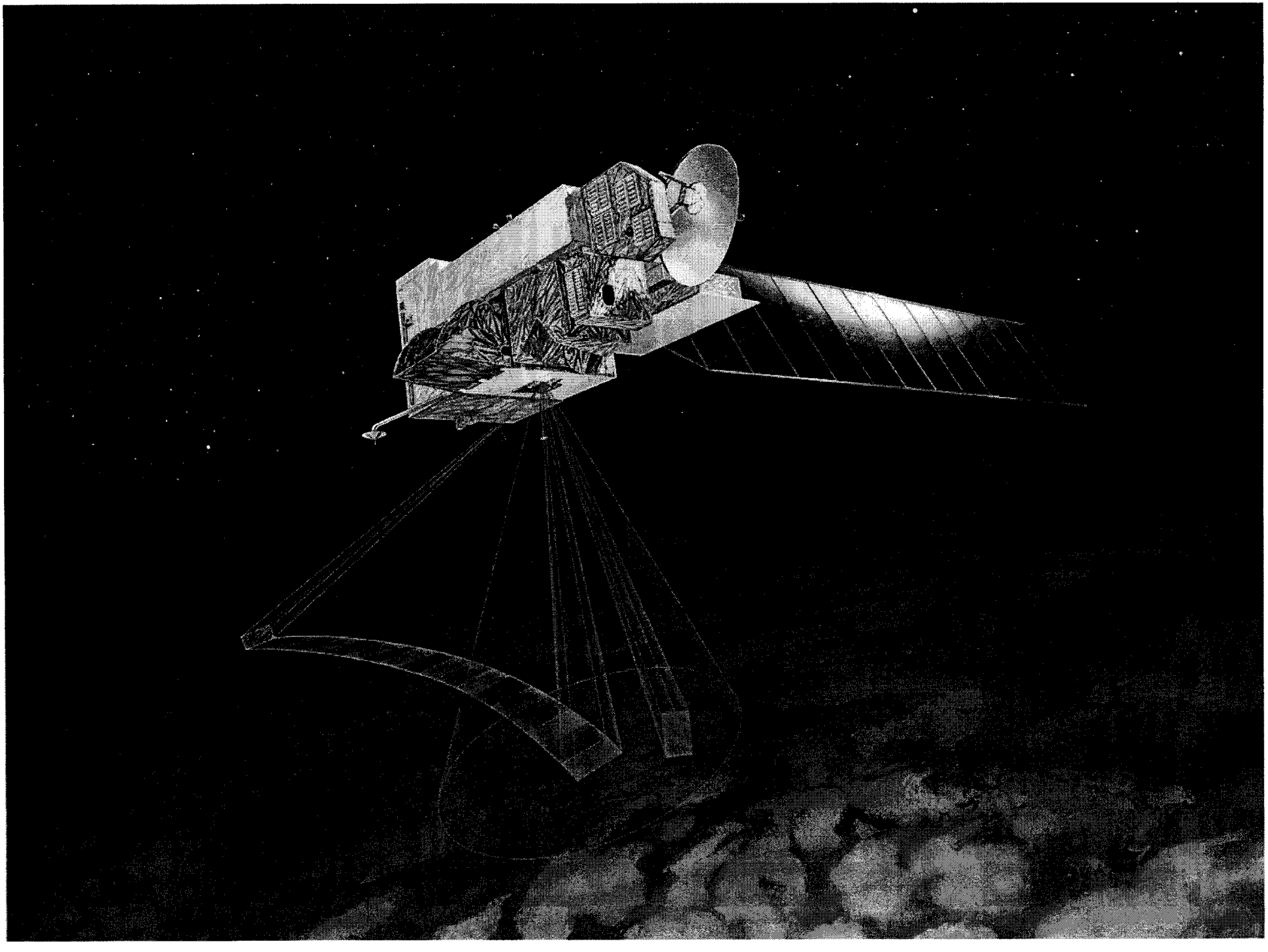
- The EOS Aura mission will help answer the following science questions:
  - Is the Earth's ozone layer recovering?
  - Is air quality getting worse?
  - How is Earth's climate changing?

EOS Aura Mission

- EOS Aura is a component of national and international efforts to understand the Earth's atmosphere.
- Third in a series of Earth Observing Satellites to study atmospheric chemistry.
- Part of the NASA Earth Science Enterprise

EOS-Aura Spacecraft

- Size:
  - Stowed - 8.8 ft h by 7.6 ft w by 22.5 ft
  - Deployed - 15.4 ft h by 55.9 ft w by 22.5 ft
- Weight: 6,542 lbs
  - Spacecraft - 3,896 lbs
  - Instruments - 2,646 lbs
- Power: 4,444 W EOL
- Orbit: 438 mi (705 km) polar, sun-synchronous, 1:45 PM ascending node
- Launch Vehicle: Delta 7920
- Launch: June 2003



Overview of the TES Project

- Designed and built at JPL
- Principal Investigator: Dr. Reinhard Beer
- Science team is geographically distributed across US and at Oxford University
- Algorithm development is lead by a JPL-based team
- Production software implementation team is at JPL
- Mission operations planned and monitored at JPL, uplink and downlink at GSFC
- Six year planned mission, plus two years' reprocessing operations after end of mission

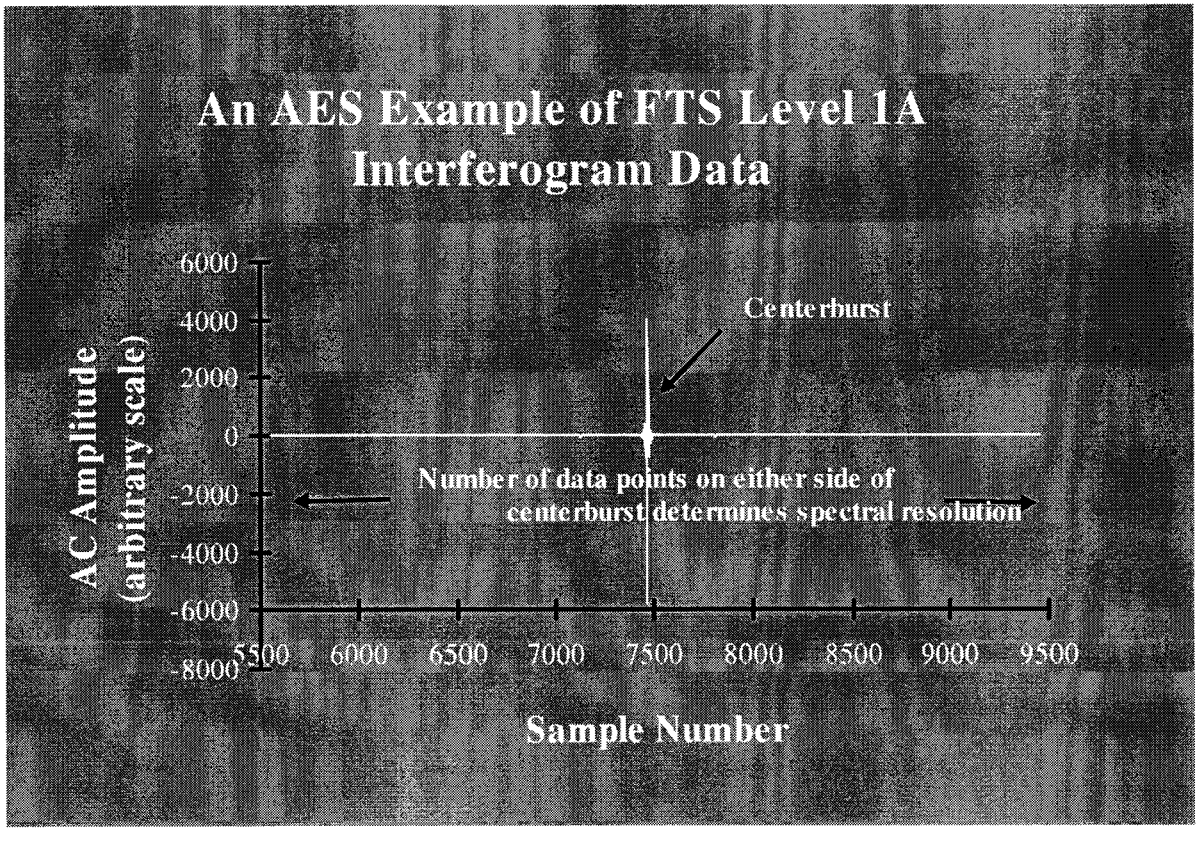
TES Science Mission Requirements

- TES shall determine, through a combination of measurement and modeling, the global distribution of tropospheric ozone and the factors that control its concentration.

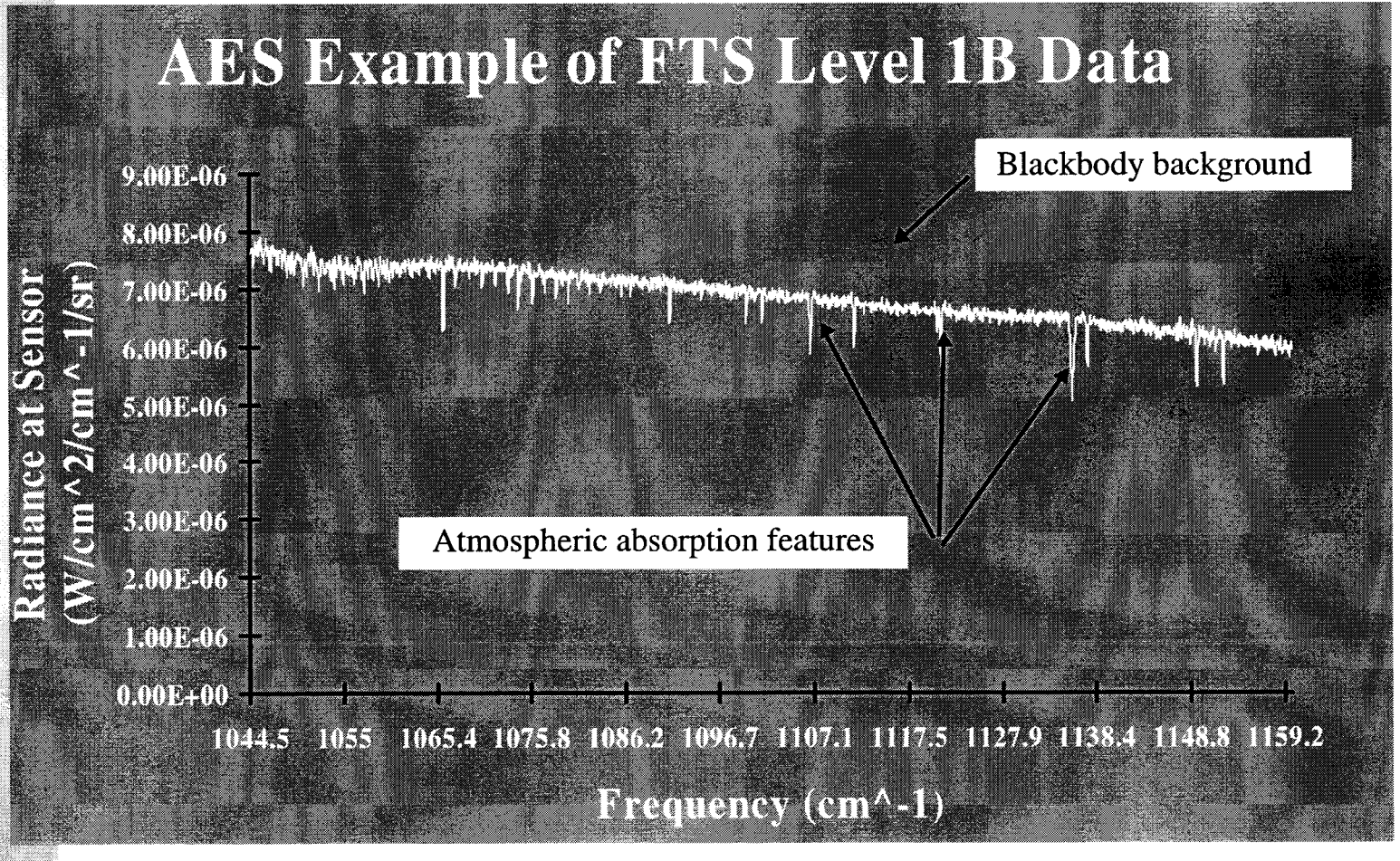
TES Standard Data Products

- Level 0: Raw instrument data
- Level 1A: Reformatted and geolocated raw data
- Level 1B: Fourier transform interferograms into spectra, and perform radiometric, phase and spectral calibration
- Level 2: Extract temperature and species concentration profiles
- Level 3: Resample Level 2 profiles onto uniform space/time grids

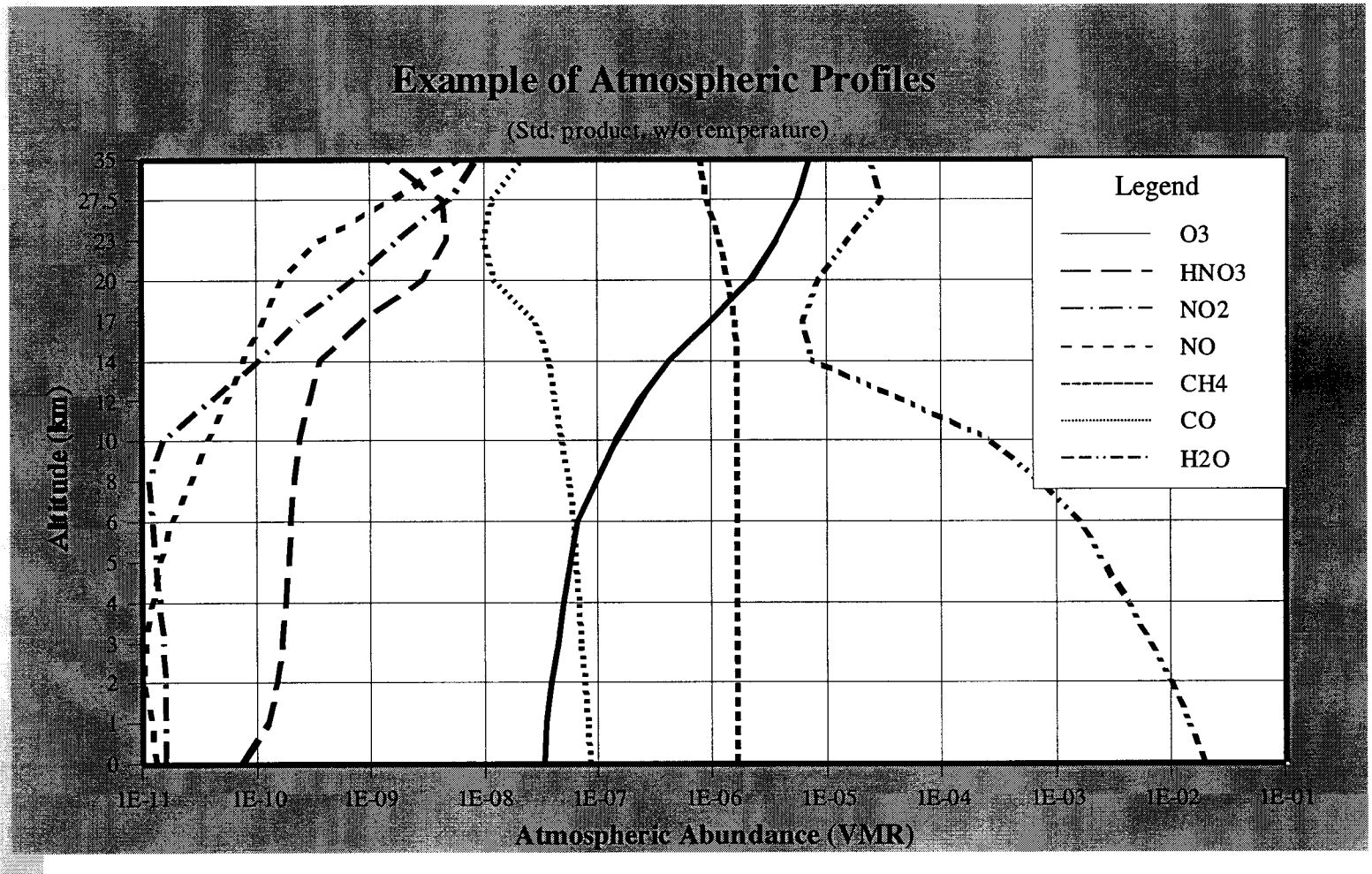
TES Level 1A Standard Product



TES Level 1B Standard Product

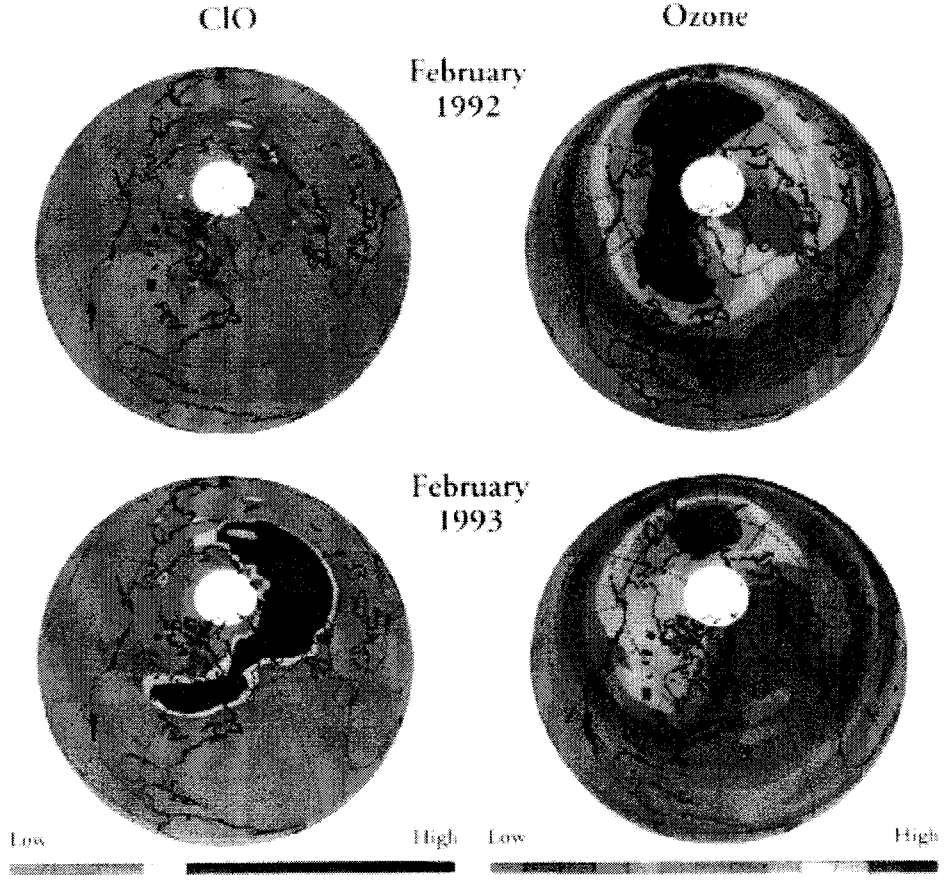


TES Level 2 Standard Product



TES Level 3 Standard Product

(example from MLS)



How Scientists Model the World

- Equations
- Text
- Geometrical abstractions
- Conceptual models

Layer Effective Pressure

The effective pressure for a layer is calculated as the total air density weighted average (the Curtis-Godson approximation), $\overline{P} = \int_L^U P \rho_{air} ds \Big/ \int_L^U \rho_{air} ds$. It can be approximately calculated as

$$\overline{P} = \frac{\sum_{sub\,layers} \int_{sub1}^{sub2} P \rho_{air} ds}{\overline{u}}. \quad (9)$$

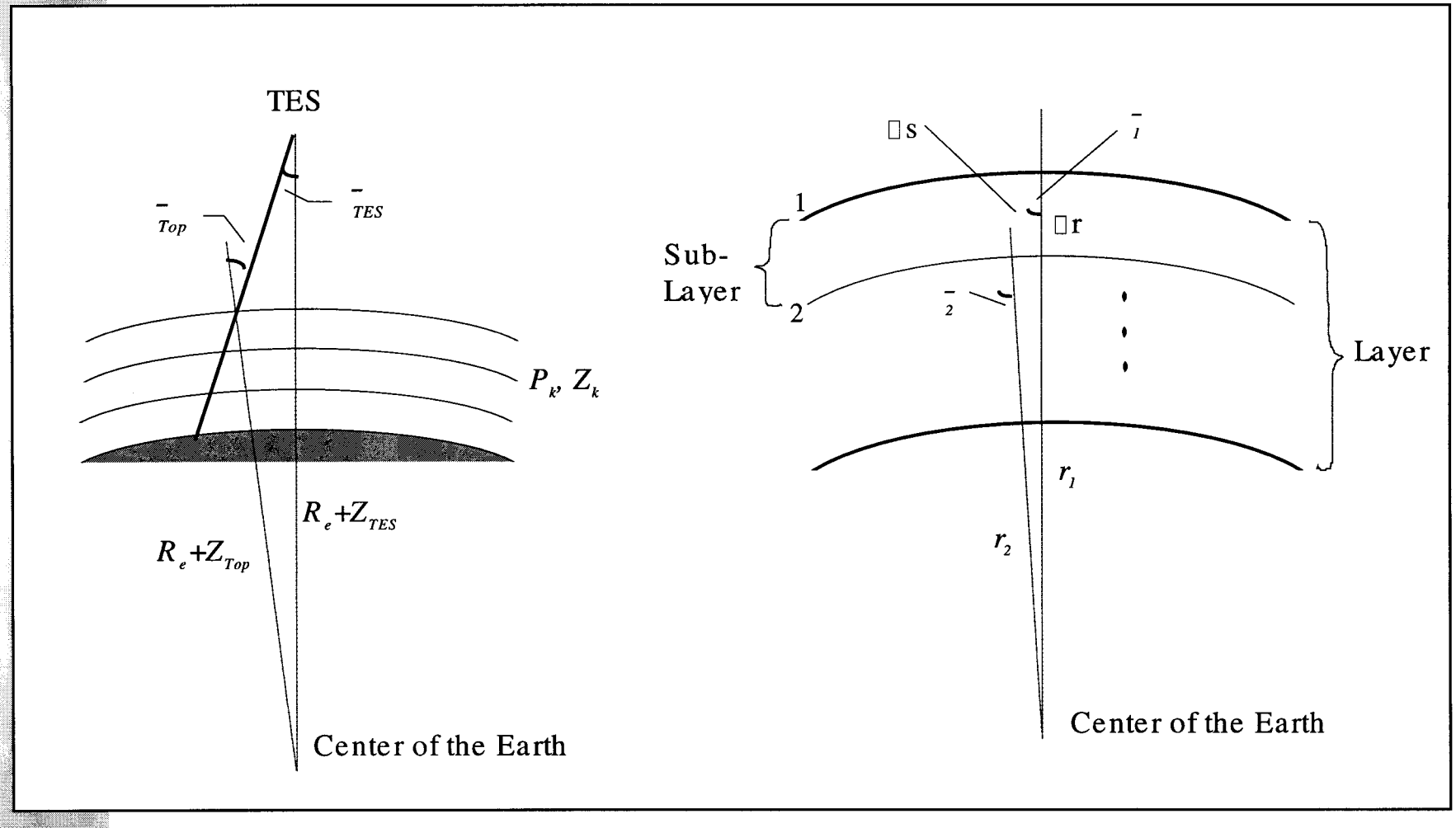
Similar to (7) the integration in the numerator can be approximately expressed as

$$\int_{sub1}^{sub2} P \rho_{air} ds = \frac{\Delta s}{\Delta r} \int_{sub1}^{sub2} P \rho_{air} dr. \quad (10)$$

Substitute (2) into (10). Equation (9) can be solved analytically,

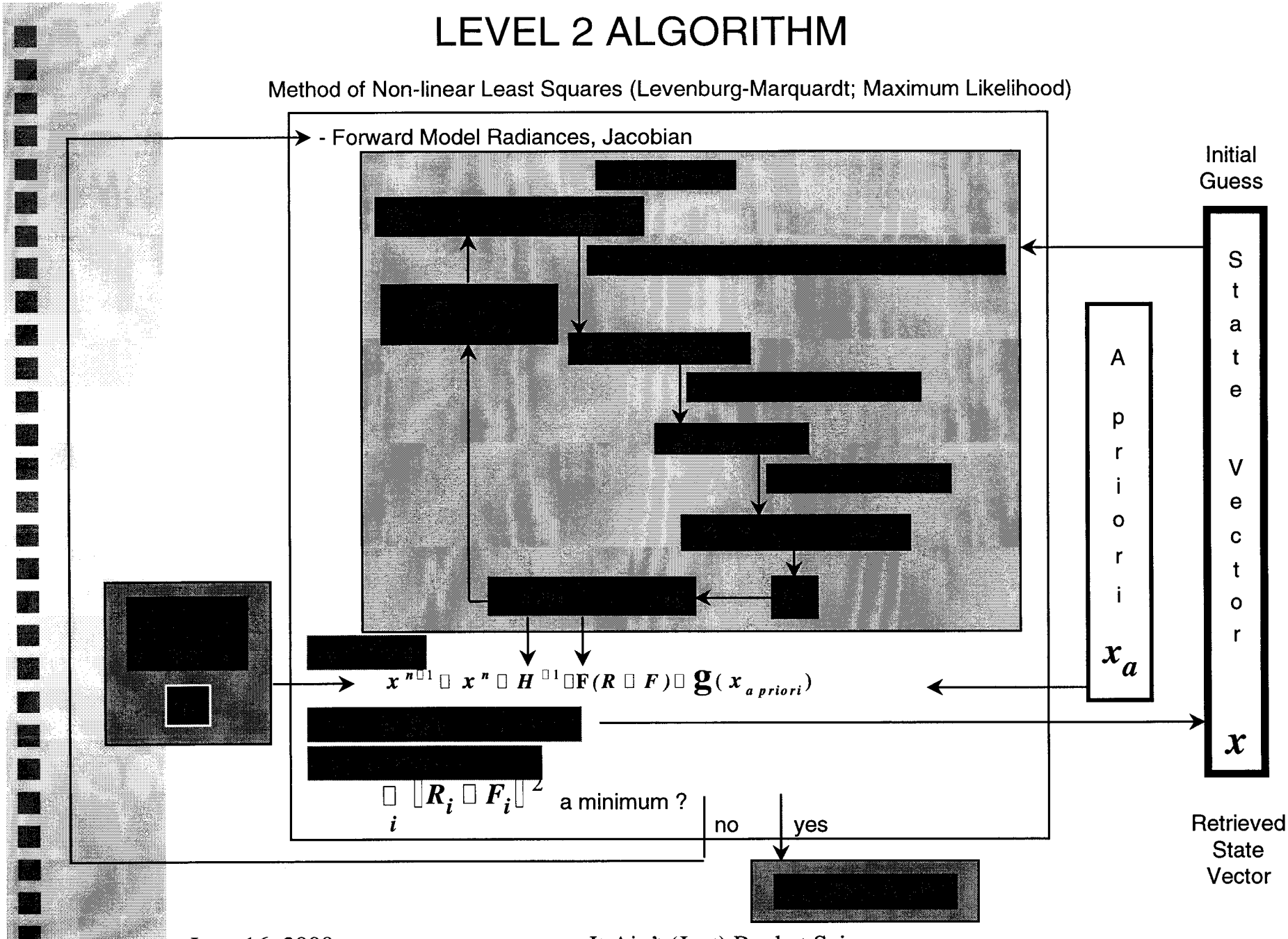
$$\overline{P} = \frac{\sum_{sub\,layers} \frac{\Delta s}{\Delta r} \frac{H_p H_\rho}{H_p - H_\rho} (P_1 \rho_1 - P_2 \rho_2)}{\overline{u}} = \frac{H_p H_\rho}{(H_p - H_\rho)\overline{u}} \sum_{sub\,layers} \frac{\Delta s}{\Delta r} (P_1 \rho_1 - P_2 \rho_2). \quad (11)$$

Again, P_1/P_2 and ρ_1/ρ_2 at r_1 and r_2 can be calculated using the interpolation rule (2). Note that ρ_1 and ρ_2 are *total air* number densities at the two sub-layer boundaries.


TES
$\bar{}_{Top}$
$\bar{}_{TES}$
P_k, Z_k
R_e+Z_{TES}
R_e+Z_{Top}
Center of the Earth
$\bar{}_1$
1
Sub-
Layer
2
$\bar{}_2$
Layer
r_1
r_2
Center of the Earth

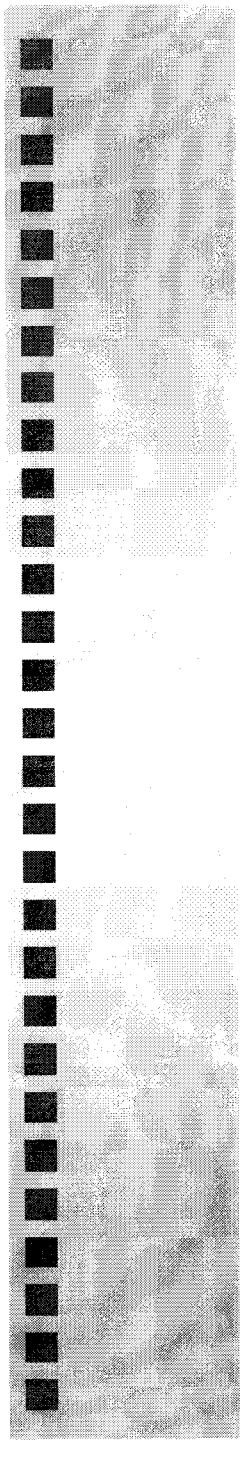
LEVEL 2 ALGORITHM

Method of Non-linear Least Squares (Levenburg-Marquardt; Maximum Likelihood)

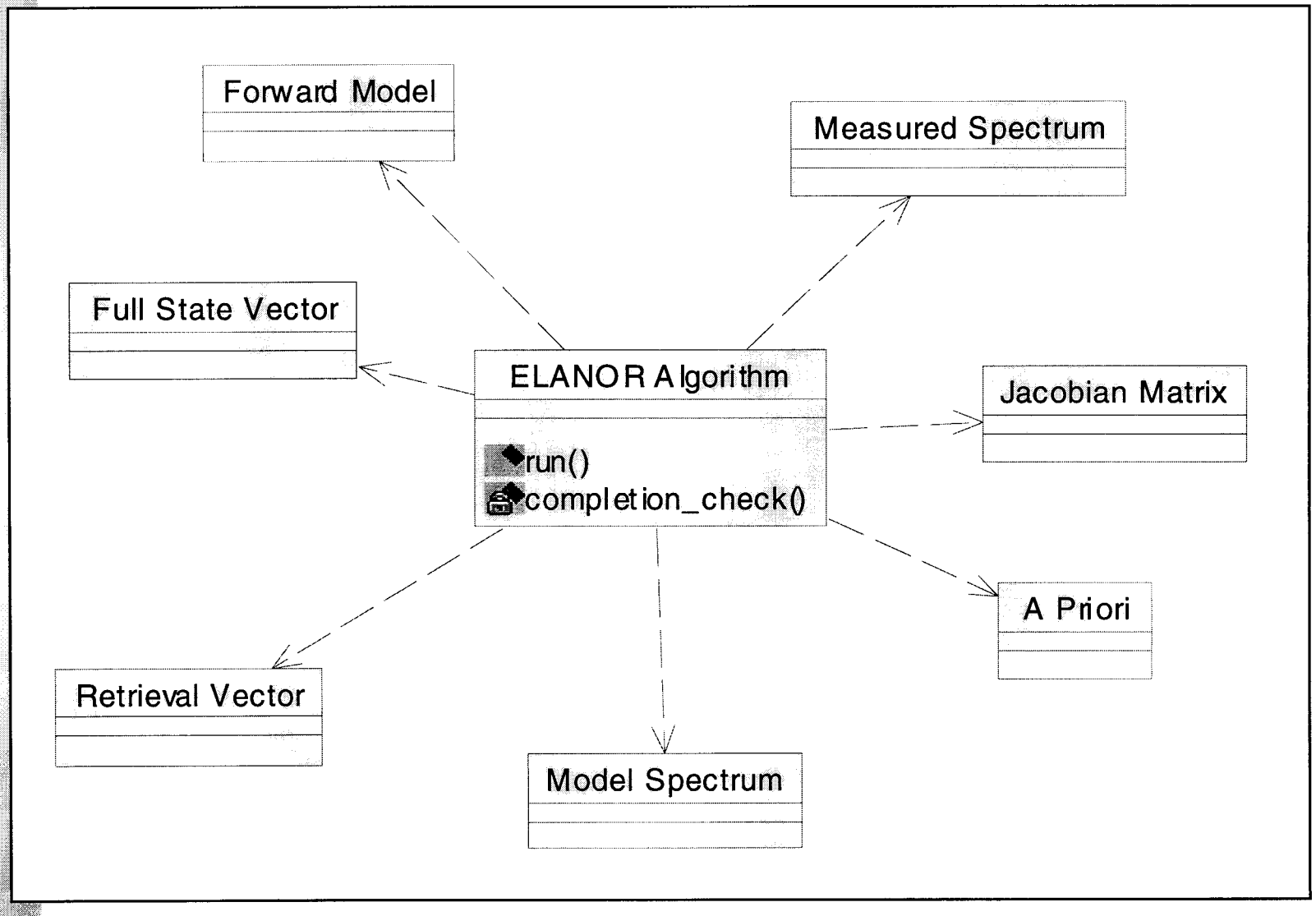


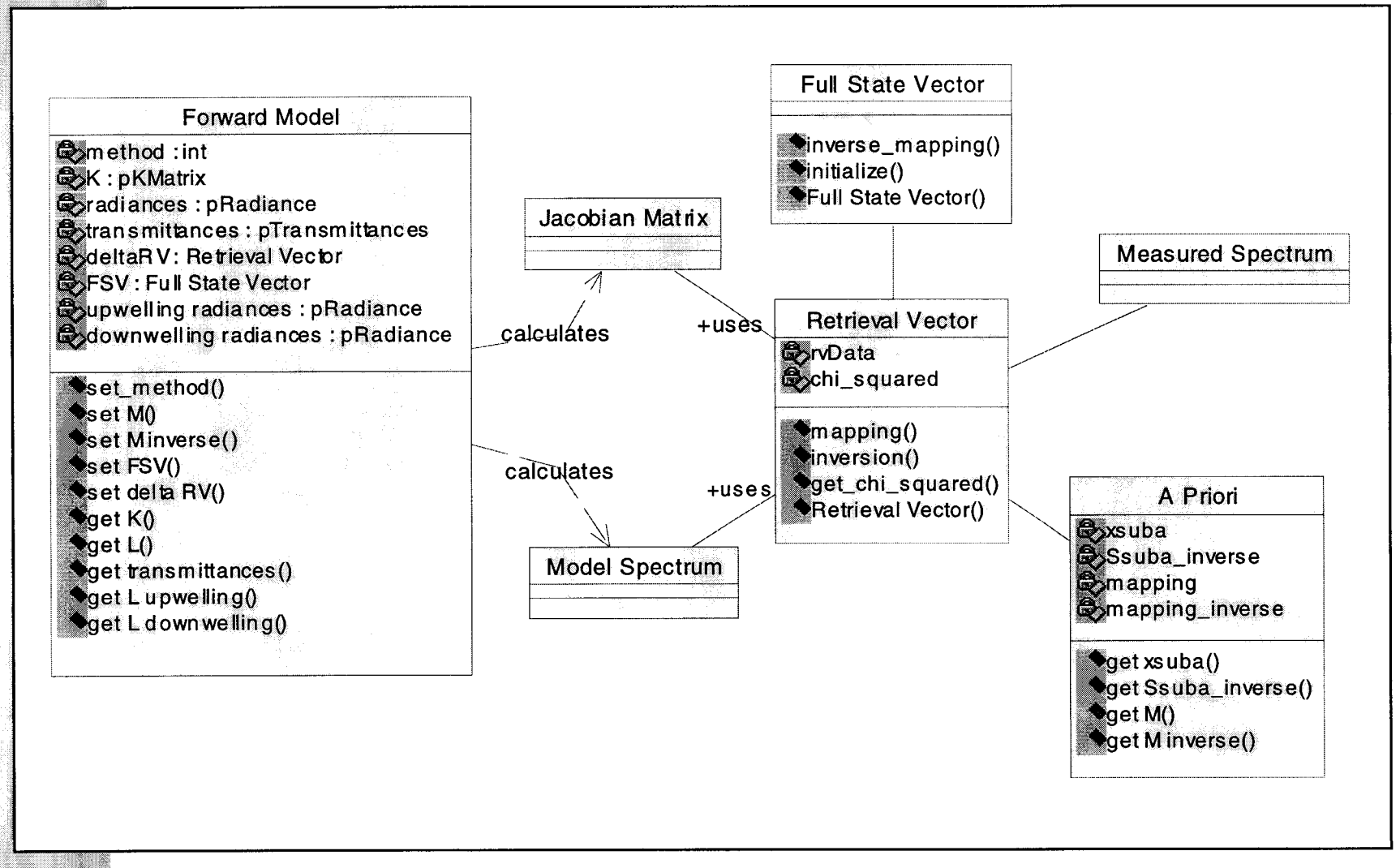
Modeling Science

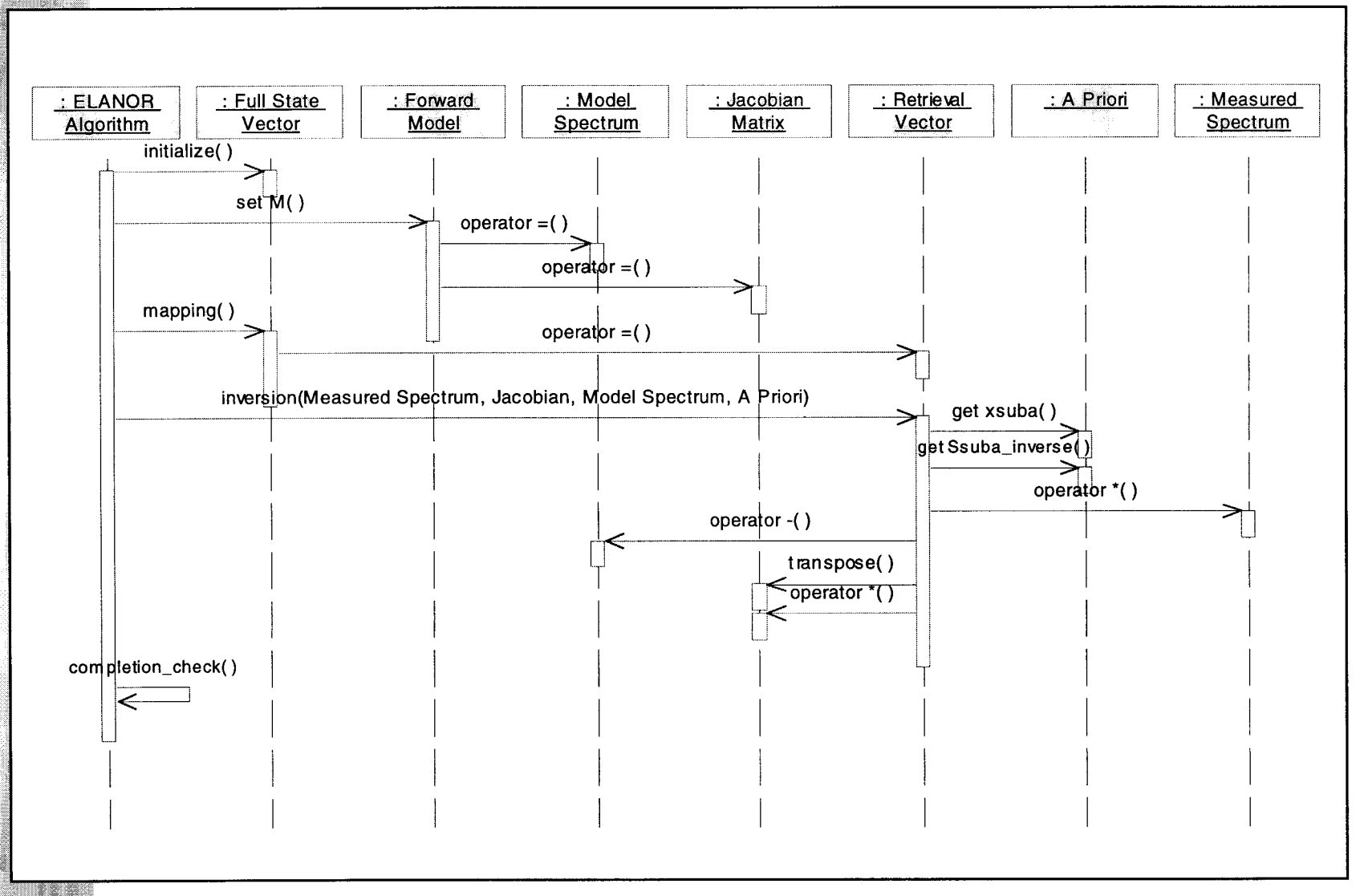
- Scientists have a highly evolved, powerful and flexible way of modeling the world
- They think in terms of their modeling paradigm
- This paradigm is in many way orthogonal to the way in which software engineers model software
- As engineers, how do we bridge the gap?



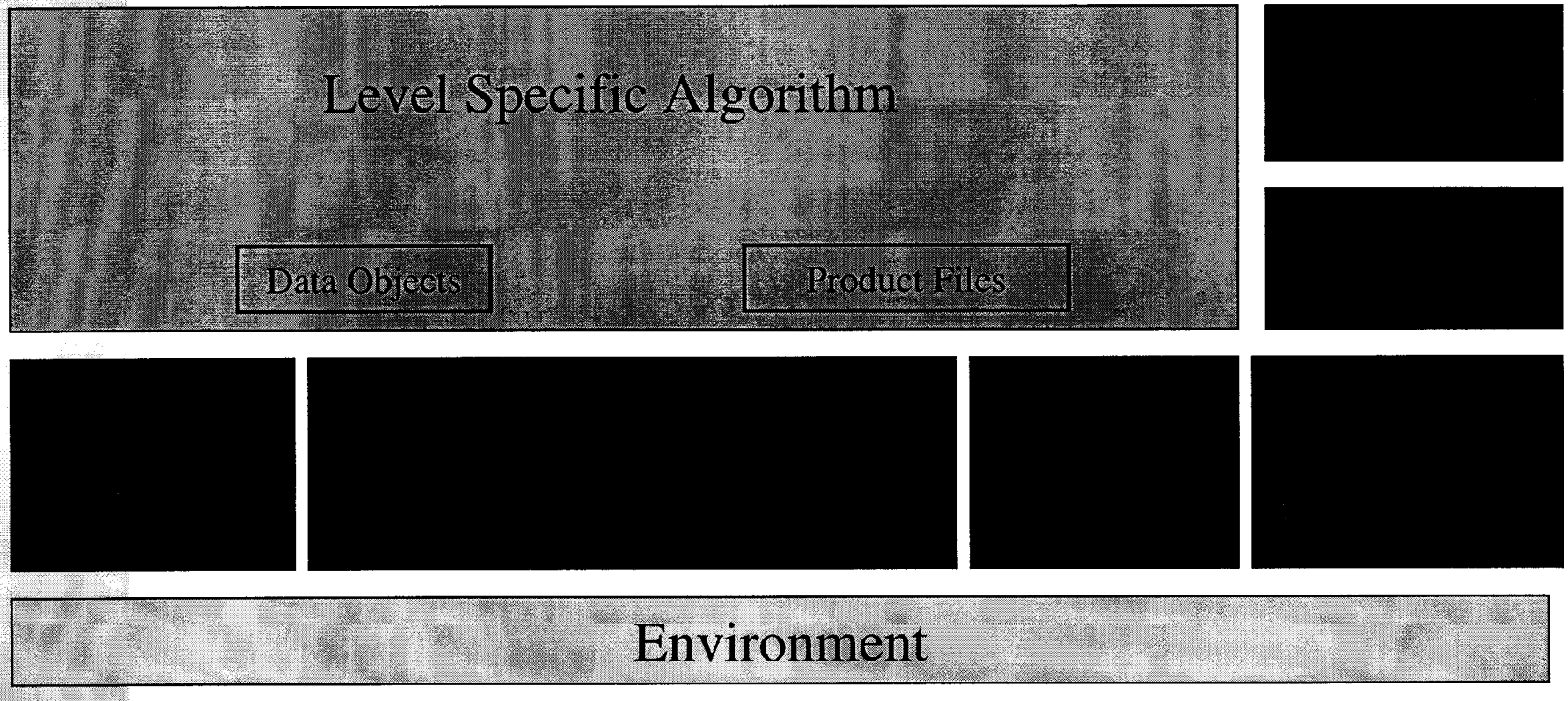
June 16, 2000 It Ain't (Just) Rocket Science


Forward Model
Measured Spectrum
Full State Vector
ELANOR Algorithm
run()
completion_check()
Jacobian Matrix
A Priori
Retrieval Vector
Model Spectrum


Forward Model
method : int
K : pKMatrix
radiances : pRadiance
transmittances : pTransmittances
deltaRV: Retrieval Vector
FSV : Full State Vector
upwelling radiances : pRadiance
downwelling radiances : pRadiance
set_method()
set M()
set Minverse()
set FSV()
set delta RV()
get K()
get L()
get transmittances()
get L upwelling()
get L downwelling()
Jacobian Matrix
Full State Vector
inverse_mapping()
initialize()
Full State Vector()
Measured Spectrum
Retrieval Vector
rvData
chi_squared
mapping()
inversion()
get_chi_squared()
Retrieval Vector()
A Priori
xsuba
Ssuba_inverse
mapping
mapping_inverse
get xsuba()
get Ssuba_inverse()
get M()
get Minverse()
Model Spectrum
calculates
+uses
calculates
+uses


: ELANOR Algorithm
: Full State Vector
: Forward Model
: Model Spectrum
: Jacobian Matrix
: Retrieval Vector
: A Priori
: Measured Spectrum
initialize( )
set M( )
operator =( )
operator =( )
mapping( )
operator =( )
inversion(Measured Spectrum, Jacobian, Model Spectrum, A Priori)
get xsuba( )
get Ssuba_inverse( )
operator *( )
operator -( )
transpose( )
operator *( )
completion_check( )

SDPS Framework



For Managers

- Selling the idea
- Framework should be a stand alone system
- Define scope of Framework and abide by it
- Iterative development fits best

For Managers

- Design meetings and reviews benefit from small groups
- High learning curve for tools and methodology
- Training all team members is essential but expensive

For Designers

- Communicating your design to new (or non) OO designers
  - Class diagrams can be too complicated
  - Object diagrams, Data Flow diagrams, and Block diagrams work best
- Traditional design tools are still very useful (e.g. DFD, State diagrams …)

- http://eos-aura.gsfc.nasa.gov/tes/